A Review of Fisheries & Aquatic Biodiversity Information for the Whanganui River catchment

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1 INTRODUCTION

The signing of the Whanganui Iwi (Whanganui River) Deed of Settlement took place in 2014 (New Zealand Government, 2021), recognising the importance of the health and well-being of the Whanganui River, which would become its own legal entity. Three years later, the Te Awa Tupua (Whanganui River Claims Settlement) Bill was passed to give effect to the Deed of Settlement. This legislation recognises the special relationship between the river and the Whanganui Iwi and provides for the river's protection and restoration by implementing Te Pā Auroa, a framework that recognises a set of intrinsic values that apply to the awa and gives the river legal personhood in law. The legislation now recognises Te Awa Tupua as an indivisible and living whole, comprising the Whanganui River from the mountains to the sea, incorporating all its physical and metaphysical elements.

As part of the Te Awa Tupua (Whanganui River Claims Settlement) Act 2017, a representative group, referred to as the Fisheries Co-ordination Group, is to be established and the Department of Conservation will be a part of this group. The purpose of this group is to coordinate activities among the organisations with responsibility for fisheries or fish habitat management in the Whanganui River catchment. It is anticipated that to advance the objectives and work programme of this group, it will be necessary to understand the existing aquatic biodiversity knowledge that is available for the catchment, and to understand where the gaps in this knowledge are.

Within this context, the purpose of this literature review is to provide a comprehensive review of aquatic biodiversity information, including research and monitoring data that may be available in published or grey literature for the entire Whanganui catchment. The goal is to summarise the existing available information about the catchment, to identify gaps in our knowledge and make recommendations for future work programmes, including the identification of management, restoration or survey work that would benefit the catchment. It is understood that there is significant customary knowledge of the fisheries and aquatic biodiversity of the Whanganui catchment, but the inclusion of this information is largely outside the scope of this review, except where this information is within the published or grey literature sourced for this review. This literature review has been funded under the Department of Conservation (DOC) Nga Awa river restoration programme. This programme is working in partnership with others to restore the biodiversity of 14 catchments that DOC has prioritised to improve ecological health and climate change resilience.

The Whanganui River extends for 290 km from its headwaters on the slopes of the Central North Island volcanoes – Tongariro, Ngauruhoe and Ruapehu – to the coast at Whanganui City (Figure 1). The catchment area covers an area of 761,100 hectares, 13% of which is classified as highly erodible land (Horizons Regional Council, 2019). The major tributaries of the Whanganui include the Manganuioteao, Retaruke, Whakapapa, Ōhura, Ōngarue, Whangamōmona, and Tāngarākau river catchments (Figure 1). While much of the catchment is covered in native bush (51%), sheep and beef farming are the other major land uses in the catchment (33%) (Horizons Regional Council, 2019).

The headwaters of the Whanganui River no longer have their natural flow regime. The Western Diversion of the Tongariro Power Development (TPD) uses a system of intakes, diversions, and canals to intercept part of the flow of the headwaters of the Whanganui River, as well as five headwater tributaries, namely the Whakapapa, Okupata, Taurewa, Mangatepopo, and Tawhitikuri streams (Genesis Energy Limited, 2000). Water has been intercepted from the headwaters of the river since 1964 (Knight, 2016), and resource consents to continue this activity were granted under the Resource Management Act 1991 during 2001. The water that is diverted from these streams into the TPD ultimately flows into the Waikato River, although minimum flows are released below the intakes to mitigate effects on the aquatic environment.

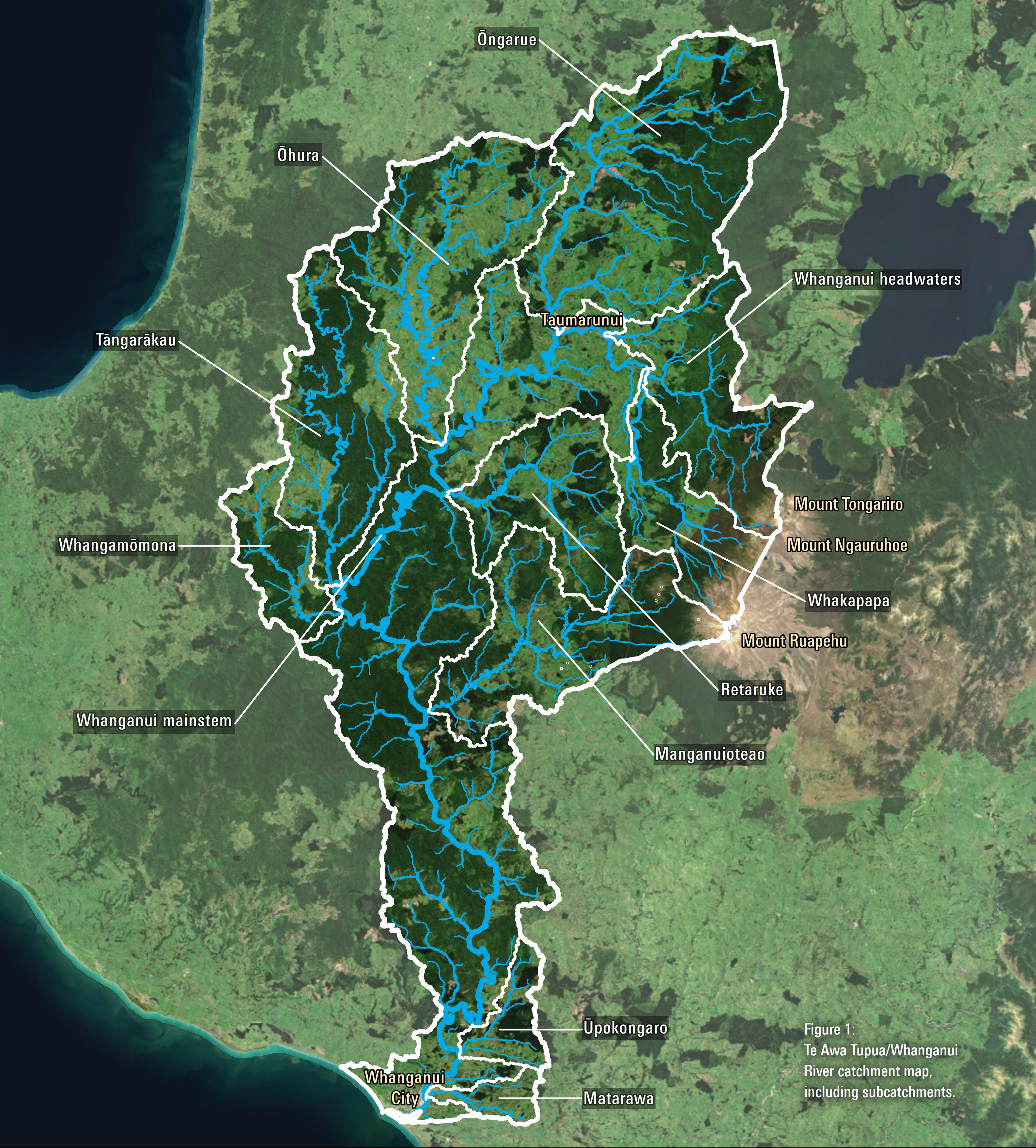

Figure 1: Te Awa Tupua/Whanganui River catchment map, including subcatchments.

Subcatchments within the Whanganui River catchment

Whanganui catchment

Whanganui subcatchments

Waterways

Stream Order 3
Stream Order 4
Stream Order 5
Stream Order 6
Stream Order 7

0 5 10 20 Kilometers

N

Layer source: Whanganui catchment and subcatchments: based on surface water management zones from Horizons Regional Council; Waterways: REC2 version 4 displaying stream orders 3-7.

2 TE AWA TUPUA SCOPING REPORT

The Te Awa Tupua scoping study prepared for Ngā Tangata Tiaki o Whanganui examined the current health and well-being of Te Awa Tupua, with a focus on the biophysical environment (Newsome *et al.*, 2017). The broad scope of the study included information on geology and soils, land cover, land use, terrestrial biodiversity, river hydrology, groundwater hydrology, water quality, aquatic ecosystems, the built environment, and governance.

The scoping study included an account of traditional fisheries on the Whanganui River, including detailed accounts of customary fishing methods for tuna and piharau, and mention of the customary catch of other smaller fish species such as grayling, ngaore, whitebait, and banded kōkopu. The report also included information on the current state of freshwater biodiversity within Te Awa Tupua, primarily presented as an analysis of fish records from the New Zealand Freshwater Fish Database (NZFFD). This section of the scoping study made several recommendations, including the establishment of a regular and consistent catchment-wide fish and macroinvertebrate monitoring programme to provide a more integrated picture of aquatic biodiversity and the health of the river system. It further recommended developing a more holistic monitoring approach by incorporating mātauranga-based assessments and the monitoring of taonga species.

3 NEW ZEALAND FRESHWATER FISH DATABASE

The New Zealand Freshwater Fish Database (NZFFD) holds records of 643 unique fish surveys within the Whanganui catchment, covering the period from 1948 to 2019 (Figure 2). While all the subcatchments identified in Figure 1 have received some fish survey attention, the Whanganui headwaters, Manganuioteao, and Ōngarue have had considerably more surveys completed than other subcatchments (Table 1). In contrast, the large Ōhura and Whangamōmona subcatchments and the small lower river subcatchments (Ūpokongaro and Matarawa), have received relatively little survey effort. Although the Whanganui (mainstem and tributaries) subcatchment has had the greatest number of surveys, this subcatchment includes many tributaries that appear to have had little or no survey attention (Figure 2).

The NZFFD records the presence of 23 freshwater fish species and three invertebrate species within the Whanganui River catchment (Table 2). Note that the NZFFD only record large invertebrate species that are typically caught during fishing surveys, such as kōura, kākahi, and freshwater shrimp. Other fish known to be present within the catchment, but not recorded in the NZFFD records, are kahawai and yellowbelly flounder. Of the 23 species recorded as present, 11 have a conservation status of *not threatened*, and a further seven of these species are *introduced and naturalised*. However, the Whanganui catchment also supports two fish species that are *threatened – nationally vulnerable* and five species that are *at risk – declining* according to the conservation classifications of Dunn *et al.*, 2017 and Grainger *et al.*, 2018 (Table 2).

Although survey effort has not been evenly distributed across the Whanganui catchment, surveys recorded in the NZFFD show that longfin eel are the most widespread fish species, being found in all identified subcatchments (Table 3). Shortfin eel, Dinah's bully, kaharore bully, common bully, torrentfish, and introduced brown trout are also relatively widespread, being found in more than 8 of the 11 identified subcatchments (Table 3). In contrast, banded kōkopu, īnanga, redfin bully, and piharau have each only been found in a few of the surveyed subcatchments. Of these species, īnanga are known to be limited to lower gradient rivers and streams by their swimming ability, but the reasons for the poor distribution of the other species are less clear. Records of pest fish within the NZFFD indicate that they are not widely distributed, with koi carp (3 records), goldfish (13 records), catfish (3 records), perch (8 records), and gambusia (5 records) having been encountered, typically during surveys of lakes and ponds within the catchment. Koi carp have been eradicated (by either pond drainage or the use of a fish poison) from four sites where they have previously been recorded in ponds within the Whanganui catchment (Rosemary Miller, Department of Conservation, personal communication).

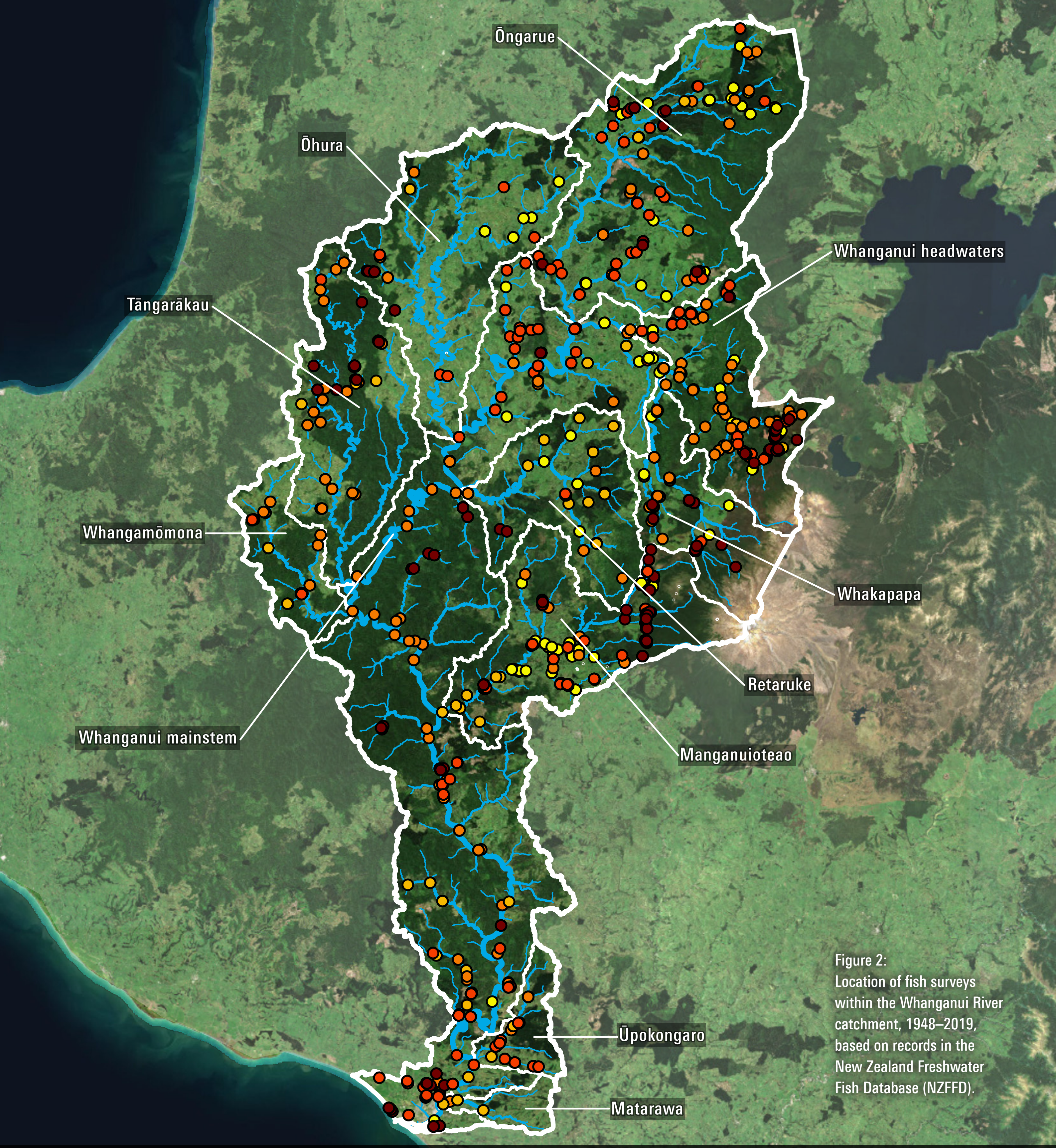

Figure 2:
Location of fish surveys within the Whanganui River catchment, 1948–2019, based on records in the New Zealand Freshwater Fish Database (NZFFD).

Locations of fish surveys within the Whanganui River catchment

Whanganui catchment

Whanganui subcatchments

Location of fish surveys

- 1915-1980
- 1981-1990
- 1991-2000
- 2001-2010
- 2011-2019

Waterways

- Stream Order 3
- Stream Order 4
- Stream Order 5
- Stream Order 6
- Stream Order 7

0 5 10 20 Kilometers

N

Layer source: Whanganui catchment and subcatchments: based on surface water management zones from Horizons Regional Council; Fish surveys: NIWA NZFFD, downloaded 28 April 2021; Waterways: REC2 version 4 displaying stream orders 3-7.

Table 1 Freshwater fish survey effort by subcatchment for the Whanganui catchment (1948–2019) as recorded in the New Zealand Freshwater Fish Database. Refer to Figure 2 for information on the location of records within each subcatchment.

Subcatchment	Number of surveys	Number of unique reaches surveyed	Oldest record	Most recent record
Whanganui – headwaters	107	71	1961	2016
Whakapapa	51	25	1961	2015
Manganuioteao River	127	73	1965	2015
Retaruke	26	22	1977	2014
Ōngarue	90	67	1948	2016
Ōhura	21	21	1948	2019
Tāngarākau	45	30	1984	2015
Whangamōmona	18	14	1989	2010
Whanganui – mainstem	150	110	1956	2017
Ūpokongaro	18	14	1989	2005
Matarawa	4	4	1989	1992

Table 2 Freshwater fish and invertebrate species recorded within the Whanganui catchment (1948 – 2019) as per the New Zealand Freshwater Fish Database. The conservation status (according to Dunn *et al*. (2017) for fish and Grainger *et al.* (2018) for invertebrates) is also given. Within this literature review, fish and invertebrates are referred to by the underlined names presented in this table. Note that fish previously identified as Cran's and upland bully have been renamed as Dinah's and kaharore bully for this catchment, as per the species distributions of Thacker *et al.* (2021).

Type	Common and Māori names	Scientific name	Family	Conservation status (Dunn *et al*., 2017; Grainger *et al*., 2018)
Native fish	Shortfin eel, tuna	*Anguilla australis*	Anguillidae	Not threatened
	Longfin eel, tuna	*Anguilla dieffenbachii*	Anguillidae	At risk – declining
	Kōaro	*Galaxias brevipinnis*	Galaxiidae	At risk – declining
	Banded kōkopu	*Galaxias fasciatus*	Galaxiidae	Not threatened
	Īnanga, atutahi, atutai, karohi, karohe	*Galaxias maculatus*	Galaxiidae	At risk – declining
	Shortjaw kōkopu	*Galaxias postvectis*	Galaxiidae	Threatened – nationally vulnerable
	Dinah's bully, toitoi	*Gobiomorphus dinae*	Eleotridae	Not threatened
	Kaharore bully, toitoi	*Gobiomorphus mataraerore*	Eleotridae	Not threatened
	Common bully, toitoi	*Gobiomorphus cotidianus*	Eleotridae	Not threatened
	Redfin bully, toitoi	*Gobiomorphus huttoni*	Eleotridae	Not threatened
	Torrentfish, panoko, panokonoko, panuku, papanoko	*Cheimarrichthys fosteri*	Mugiloididae	At risk – declining
	Lamprey, piharau	*Geotria australis*	Geotriidae	Threatened – nationally vulnerable
	Yelloweye mullet, kanae aua	*Aldrichetta forsteri*	Mugilidae	Not threatened
	Grey mullet, kanae	*Mugil cephalus*	Mugilidae	Not threatened
	Common smelt, ngaore	*Retropinna retropinna*	Retropinnidae	Not threatened
	Black flounder, pātiki mohoao	*Rhombosolea retiaria*	Pleuronectidae	Not threatened
Introduced fish	Brown trout	*Salmo trutta*	Salmonidae	Introduced & naturalised
	Rainbow trout	*Oncorhynchus mykiss*	Salmonidae	Introduced & naturalised
	Koi carp	*Cyprinus carpio*	Cyprinidae	Introduced & naturalised
	Goldfish	*Carassius auratus*	Cyprinidae	Introduced & naturalised
	Catfish	*Ameiurus nebulosus*	Ictaluridae	Introduced & naturalised
	Perch	*Perca fluviatilis*	Percidae	Introduced & naturalised
	Gambusia	*Gambusia affinis*	Poeciliidae	Introduced & naturalised
Invertebrates	Freshwater mussel, kākahi	*Echyridella menziesi*	Unionidae	At risk – declining
	Freshwater shrimp	*Paratya curvirostris*	Atyidae	Not threatened
	Freshwater crayfish, kōura	*Paranephrops planifrons*	Parastacidae	Not threatened

Table 3 Freshwater fish species present by subcatchment for the Whanganui catchment (1948–2019) as recorded in the New Zealand Freshwater Fish Database (NZFFD). The conservation status (according to Dunn *et al*. (2017) for fish and Grainger *et al.* (2018) for invertebrates) is also given in parenthesis in the first column. Refer to Figure 2 for further catchment information. Asterisks identify pest fish species that are recorded in the NZFFD, but have been eradicated by the Department of Conservation where possible.

	Whanganui – headwaters	Whakapapa	Manganuioteao	Retaruke	Ōngarue	Ōhura	Tāngarākau	Whangamōmona	Whanganui – mainstem	Ūpokongaro	Matarawa
Number of fish species recorded in catchment	10	7	15	10	13	9	11	7	22	11	3
Shortfin eel (not threatened)	✓	✓	✓	✓	✓	✓	✓		✓	✓	✓
Longfin eel (at risk – declining)	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Kōaro (at risk – declining)	✓		✓	✓			✓	✓	✓		
Banded kōkopu (not threatened)			✓				✓		✓		
Īnanga (at risk – declining)			✓						✓	✓	
Shortjaw kōkopu (threatened – nationally vulnerable)			✓		✓	✓	✓	✓	✓		
Dinah's bully (not threatened)	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	
Kaharore bully (not threatened)	✓	✓	✓	✓	✓	✓	✓	✓	✓		
Common bully (not threatened)	✓		✓	✓	✓		✓	✓	✓	✓	
Redfin bully (not threatened)			✓				✓		✓		
Torrentfish (at risk – declining)	✓	✓	✓	✓	✓		✓	✓	✓		
Piharau (threatened – nationally vulnerable)			✓						✓	✓	
Yelloweye mullet (not threatened)									✓		
Grey mullet (not threatened)										✓	
Ngaore (not threatened)			✓	✓	✓				✓	✓	✓
Pātiki (not threatened)									✓		
Brown trout (introduced & naturalised)	✓	✓	✓	✓	✓		✓		✓	✓	
Rainbow trout (introduced & naturalised)	✓	✓	✓	✓	✓				✓		
*Koi carp (introduced & naturalised)						✓			✓	✓	
*Goldfish (introduced & naturalised)	✓				✓	✓			✓	✓	
*Catfish (introduced & naturalised)					✓	✓			✓		
*Gambusia (introduced & naturalised)						✓			✓		
Perch (introduced & naturalised)									✓		
Kākahi (at risk – declining)	✓	✓	✓		✓			✓	✓	✓	
Freshwater shrimp (not threatened)	✓	✓	✓		✓		✓	✓	✓	✓	
Kōura (not threatened)	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	

4 BIODIVERSITY LITERATURE REVIEW

4.1 Fish

The Whanganui River Report (Waitangi Tribunal, 1999) provides a historical perspective on the fisheries of the Whanganui catchment and the plentiful food supply that it has traditionally provided for Whanganui iwi. The report refers to information provided by fisheries biologist Ronald Little, who listed 18 species of native freshwater fish that the river was known to support. These included non-migratory species (kaharore bully, Dinah's bully, and giant kōkopu), migratory species that use the sea for part of their lifecycle (shortfin and longfin eel, common bully, redfin bully, torrentfish, īnanga, and piharau), marine species that use or feed in freshwater (yellow eyed mullet, grey mullet, pātiki, yellow belly flounder, kahawai, and ngaore), as well as kōura and kākahi.

Traditional fisheries on the Whanganui River were dominated by tuna, with over 300 pā tuna (eel fishing weirs) located along the river at the peak of the fishery (McDowell, 2011). The piharau fishery was also important, but while over 90 piharau weirs are thought to have existed on the river, the quantity of piharau caught was considerably lower than for tuna. Other important fisheries on the river included kahawai, grey mullet, juvenile eels/elvers, kākahi, kōura, and ngaore (McDowell, 2011).

Extensive knowledge of the life stages, seasonality, and location of fish species form the basis of traditional fishing practices on the Whanganui River. This traditional knowledge of the river and the historical state of the river fisheries provide a basis with which to compare the current state of the Whanganui River fisheries (Waitangi Tribunal, 1999). On this basis, the contemporary fishery is described as declining, with an especially notable decrease in catches of tuna, piharau, and kākahi. Among the reasons suggested for the decline in the Whanganui fishery are reduced water levels, gravel abstraction, and bush clearance.

New Zealand rivers do not typically support a high diversity of freshwater fish species and the Whanganui River is no exception. In a study of the distribution and abundance of freshwater fish in New Zealand rivers, Jowett & Richardson (1996) found that the rivers in their study supported a consistent but low diversity of native fish species. Further, the fish diversity of the Whanganui River has been described as not exceptional or distinctly impoverished, and the fish fauna is not considered notable on a regional or national scale (Rowe *et al.,* 1989, cited in McDowell, 2011). In their study of over 30 medium to large New Zealand rivers, Jowett & Richardson (1996) included a site in the Whanganui River. The overall finding of their study was that fish species richness was highest at low elevations and that densities of diadromous species tended to decrease with elevation. They suggested that the diadromous habit of many native fish species was a key influence on their distribution, with elevation a more important factor than distance from the sea.

Rowe *et al.* (1989) undertook an electrofishing survey of 35 sites in the lower Whanganui catchment in winter 1989, concentrating on catchments whose confluences with the Whanganui River were below Taumaranui. Catchments surveyed included the Retaruke, Tāngarākau, Ōngarue, and Whangamōmona rivers in the middle reaches and Mangoihe, Ahuahu, Kauarapaoa, Aramaire, Pitangi, Ūpokongaro, and Matarawa streams in the lower reaches of the Whanganui River catchment. These catchments had previously received little attention in terms of fish surveys. They found that 17% of sites had no fish present, 43% had one species, 29% had two species, and 12% of sites had three or more species. Sites on tributaries lower down the catchment typically supported a higher diversity of fish species, and a site on Pitangi Stream was the only location in this study to support more than five species. The survey revealed that longfin eel were the most widespread species, followed by shortfin eel and common bully, and that īnanga, kōkopu and kōaro were sparsely distributed at surveyed sites. They concluded that the Retaruke, Tāngarākau and Whangamōmona rivers were relatively depauperate in terms of fish species and fish density compared to other North Island rivers. Although, because the survey was undertaken during winter there may be a seasonal aspect to this low diversity and abundance. They suggested that the low diversity and abundance of native fish could be a cause for concern but suggested that a comprehensive summer survey would be needed to confirm this.

More recent fish surveys have focused on streams that have not been previously surveyed and those where habitat is predicted to be suitable. McQueen (2014) surveyed fish in six tributaries of the mid-Whanganui catchment during summer 2014. The survey sites for this work were identified using the Freshwater Ecosystems of New Zealand (FENZ) geodatabase. The survey used spotlighting to detect the species present and so their abundance could be recorded. These surveys found low diversity and abundance of fish at most sites, despite several sites being located within native forest, with excellent habitat and water quality. The investigation concluded that although longfin eels were found at all sites, the presence of waterfalls and chutes were preventing non-climbing migratory fish species from accessing large areas of suitable habitat within the mid-Whanganui catchment. They found that many tributaries joined the Whanganui River by way of a waterfall or chute, thus preventing access to the entire tributary for non-climbing species and concluded that the presence or absence of waterfalls was a major limiting factor in terms of fish diversity. As part of their report, fish survey data from the NZFFD were examined and they observed that non-climbing fish species were rarely found outside of the mainstem of the Whanganui River, whereas climbing species were more often recorded in tributaries. Many of the catchment's known fish barriers are natural waterfalls, although culverts and other man-made obstacles may be responsible in some cases. The implications of this finding are that the fish are typically confined to the mainstem of the Whanganui River, where habitat and water quality are more highly impacted by agricultural land use and are thus largely prevented from accessing the more pristine tributaries in the catchment, through the presence of predominantly natural barriers. This offers a potential explanation for the low diversity and abundance of fish species in parts of the Whanganui catchment.

While scientific surveys of freshwater fish are distributed throughout the Whanganui catchment (Figure 2), fish survey information is limited for the lower reaches of the Whanganui River because of the difficulty of undertaking fish surveys in large rivers. However, Hicks & Bell (2003) successfully used an electrofishing boat to survey eight sites in the lower Whanganui River and concluded that fish densities were relatively low. Although the catch efficiency of the electrofishing boat is not well understood, they estimated that they would have caught around half of the fish that were present. Eleven species were caught over the eight sites surveyed by the electrofishing boat in the lower Whanganui River (between the confluence with Kauarapaoa Stream and Aramoho). Ngaore were most abundant, being present at seven of the eight sites, with 194 individuals caught in total. However, other than ngaore, only 30 individual fish were caught in this survey, which included shortfin eel, unidentified eel, īnanga, juvenile galaxiids, common bully, yelloweye mullet, grey mullet, pātiki, yellowbelly flounder, and brown trout. The electrofishing boat did not capture any pest fish at survey sites in the Whanganui River.

There has been considerable focus and relatively more documentation of surveys in the upper Whanganui catchment. Much of this work has been completed in relation to the resource consenting for the Tongariro Power Development (TPD). There is limited survey information available before the commissioning of the TPD western diversion intakes, but some pre-diversion fish surveys were reported by Woods (1964), although this report is not readily available now. Genesis Energy Ltd (2000) reported that prior to the commissioning of the western diversion, low densities of rainbow trout and longfin eels were present upstream of the intakes, in the Mangatepopo, Okupara, Tawhitikuri and Whanganui headwaters. In contrast, no fish were recorded in the Whakapapanui and Whakapapaiti streams. Woods (1964) also observed that tuna densities decreased upstream from Taumarunui. Downstream of the intake locations, rainbow trout, brown trout, longfin eel, shortfin eel, and Dinah's bully were found, prior to construction. Similarly, Stephens (1988) observed that the fish fauna of the Whanganui headwater tributaries was limited to tuna, galaxiids and non-migratory species, because only the strongest upstream migrants make it that far. Boubée (2000) indicated that the fish fauna had remained the same since the commencement of the Western Diversion, with rainbow trout, brown trout and longfin eels still occurring upstream of most of the diversions.

Further investigations of the upper Whanganui catchment were undertaken to support the assessment of environmental effects for the reconsenting of the TPD (Genesis Energy Limited, 2000; Jowett *et al.*, 1999). Habitat measurements at sites downstream of the western diversion intakes indicated that the effects of the diversions decreased with distance downstream because of increasing tributary inflows. This work showed that the reduced flows downstream of intakes reduced the amount of habitat available for fish and benthic invertebrates, with a decrease in riffle and run type habitats and an increase in pool habitats below intakes. Fish species found in the upper Whanganui catchment below the western diversion intakes include longfin eel, shortfin eel, rainbow trout, brown trout, Dinah's bully, kaharore bully, kōaro, and torrentfish. Above the intakes, the only species recorded are rainbow trout, brown trout, and longfin eel. There is no provision for fish passage past intake structures, because of the existence of natural barriers at these locations and because of the low densities of migratory species at this elevation and distance from the sea (Genesis Energy Limited, 2000). It is suggested that waterfalls near intake sites on the Mangatepopo, Tawhitikuri, Taurewa, Okupata, Papamanuka, and Whakapapanui streams were likely to have been a barrier to several fish species prior to the establishment of the western diversion intakes. However, in evidence to the resource consent hearing, Boubée (2000) concluded that fish abundance has reduced upstream of the western diversion intakes because of the lack of fish passage over these structures and that fish distribution and abundance has been impacted by flow regimes and reduced habitat downstream of the intakes. Even so, they indicate that these streams would not be expected to support a large population of native fish because of their distance from the coast and high elevation.

A fish monitoring programme was established at sites below the intake structures on the Whakapapa, Mangatepopo, and Whanganui streams in 2007 (Genesis Energy Ltd, 2015). The purpose of this monitoring was to assess the recolonisation of these sites with fish following the establishment of minimum flows for these streams. An electrofishing survey of these sites during 2014 found low densities of fish but recorded the presence of rainbow trout, brown trout, and longfin eel in each of the three streams, with shortfin eel only being found at sites in the Whanganui River (Genesis Energy Ltd, 2015; Smith *et al.*, 2015).

4.1.1 Piharau

For the entire Whanganui catchment, there are only three records of piharau in the NZFFD. These represent three separate sampling occasions, in 1978, 1979 and 2000. Electric fishing and netting are known to be ineffective for the survey of juvenile and adult piharau (Baker *et al.*, 2016), and as they are not often recorded during surveys, such survey data does not provide an accurate assessment of how common they are within a catchment.

Traditional knowledge of piharau in the catchment may provide more information on the distribution and abundance of this species. It has been reported that, historically, up to 600 piharau may be caught in one night using traditional fishery methods (weir or utu piharau), and that this would amount to several thousand over a season (Department of Conservation, 2000).

To overcome the inherent difficulties in surveying piharau, NIWA has developed a piece of equipment called a Polar Organic Chemical Integrative Sampler (POCIS), which may be used to measure the concentrations of piharau pheromones in stream water (Baker *et al.*, 2016). The detection of the pheromone indicates the presence of piharau in the sampled waterway and the concentration of the pheromone may be used to estimate larval abundance. This technique has been used to make semi-quantitative estimates of larval piharau abundance at 30 sites in the Whanganui catchment (Baker *et al.*, 2016). The study found that pheromone concentrations were above detection limits at nine of the sampled sites, with the highest concentrations measured for Mangapurua Stream, resulting in an estimate of greater than 500 larval piharau for that stream catchment. Other rivers and streams where piharau pheromones were detected were Otunui Stream, Ruatiti Stream, Orautoha Stream, Ōhura River, Makirikiri Stream, Waikaka Stream, Kakahi Stream, and Hikumutu Stream. The results of this study suggested that mid-catchment waterways are providing important spawning and rearing habitat, with the highest larval densities estimated for the Mangapurua Stream and two tributaries of the Manganuioteao River (Baker *et al.*, 2016). This study provides recommendations of further work to address the lack of knowledge of piharau distribution in the Whanganui catchment, including a resurvey for several sites where samplers were disturbed during the original study and further work to ground truth the POCIS survey results and determine the extent of critical habitats for both spawning and larval rearing.

4.1.2 Longfin & Shortfin Eel

Records from the NZFFD provide an overview of the distribution of shortfin and longfin eel in the Whanganui catchment (Figure 3). This shows that both longfin and shortfin eel are dispersed throughout the catchment, with longfin eel being recorded as present within all the subcatchments identified in this review, and shortfin eel being found in all but the Whangamōmona subcatchment (Table 3). Over all surveys recorded in the NZFFD for the Whanganui catchment, longfin eel was recorded in 54% of surveys, whereas shortfin eel was found in 14% of surveys, suggesting that longfin eel is more widespread and abundant than shortfin eel in this catchment (Table 4).

Table 4 Summary of New Zealand Freshwater Fish Database records of shortfin and longfin eel in the Whanganui catchment (1948–2019). Refer to Figure 3 for information on the distribution of these records within the catchment.

Species	Number of records	Total number of fish recorded	Mean fish abundance (per record)	Range in abundance (per record)
Shortfin eel (*Anguilla australis*)	88	653	7.4	1 to 59
Longfin eel (*Anguilla dieffenbachii*)	345	2629	7.6	1 to 100

Surveys and monitoring undertaken as part of the TPD establishment and consenting provide some information on tuna distribution and abundance in the upper Whanganui catchment. Evidence provided by Boubée (2000) for the TPD resource consent hearings summarised the findings of Woods (1964). Boubée (2000) reported that tuna densities decreased upstream from Taumarunui and ranged between 0.4 to 8.4 tuna per 100 m^2 before the TPD was commissioned. Using similar assumptions, tuna densities were estimated at around 7.2 tuna per 100 m^2 in 1999. Boubée (2000) suggested that tuna would have extended further upstream prior to the TPD for some tributaries, but that natural barriers to fish passage existed in several of these streams before the intakes were constructed.

Following the establishment of minimum flows below TPD intakes, fish monitoring programmes were established by Genesis Energy Ltd. Baldwin *et al.* (2012) undertook an electrofishing survey of the Whanganui, Mangatepopo and Whakapapa rivers below the Tongariro Power Development (TPD) western diversion intakes. They found that longfin and shortfin eels had re-established at sites below the intakes that were dry prior to the establishment of minimum flow requirements for these rivers. The range of sizes of longfin eels recorded at these sites indicated that regular recruitment was occurring for the reaches below the TPD intakes. Smith *et al.* (2015) also undertook fish monitoring as part of the TPD monitoring programme and found that rainbow trout, brown trout, longfin and shortfin eels were the species present. They also reported that within a three-year period, 77 tuna heke (downstream migrant tuna) were collected from the Wairehu Canal drum screens, with the majority of these being released live to the headwaters of the Whanganui to continue their journey downstream. These were typically large females that were estimated to be younger than the establishment of the power scheme, suggesting that a small population of tuna still exists within the limits of the scheme.

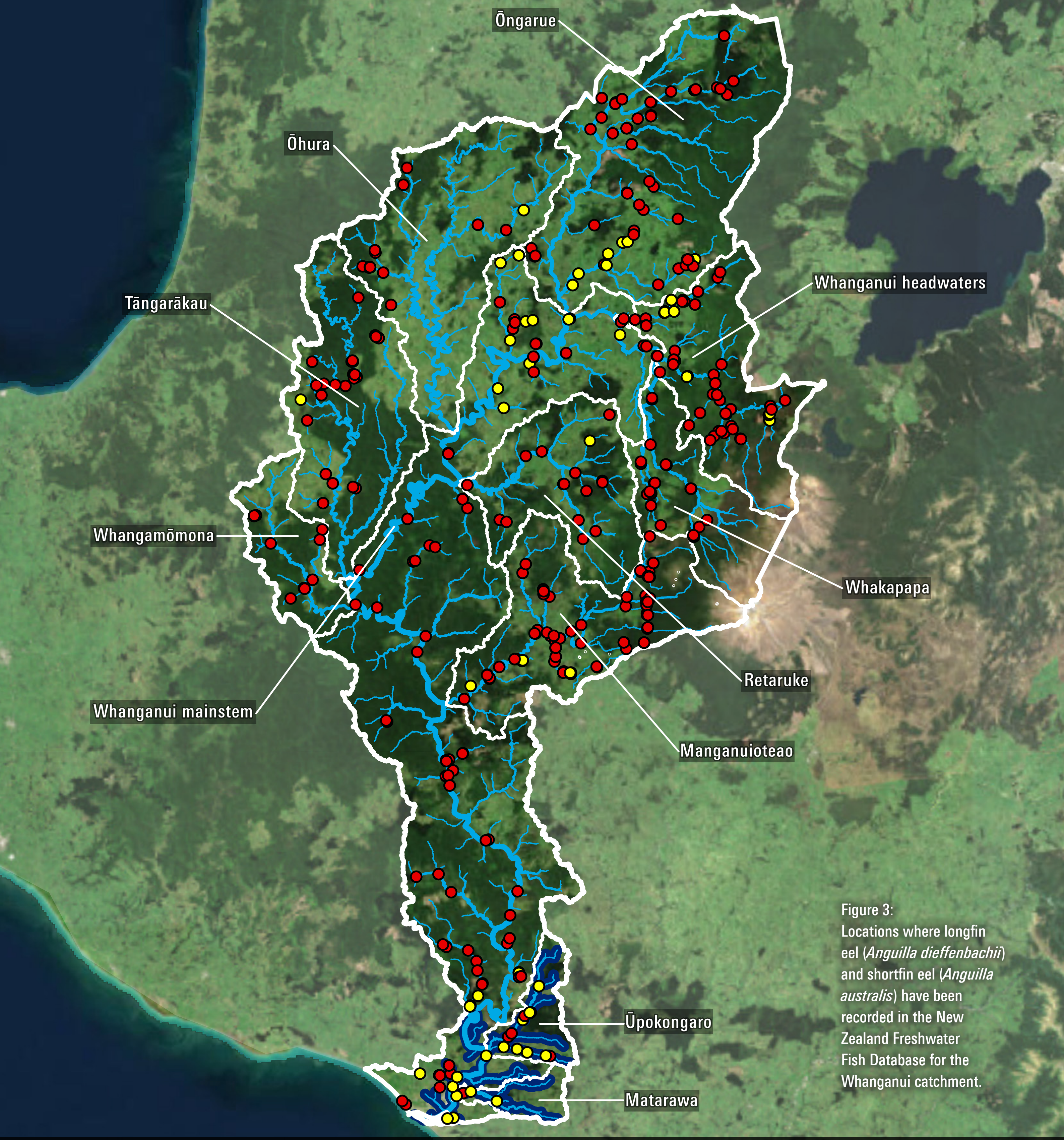

Figure 3: Locations where longfin eel (*Anguilla dieffenbachii*) and shortfin eel (*Anguilla australis*) have been recorded in the New Zealand Freshwater Fish Database for the Whanganui catchment.

Recorded locations of eels within the Whanganui River catchment

Whanganui catchment

Whanganui subcatchments

Location of fish surveys

Longfin eel (*Anguilla australis*)

Shortfin eel (*Anguilla dieffenbachii*)

Commercial eel fishery

Waterways

Stream Order 3

Stream Order 4

Stream Order 5

Stream Order 6

Stream Order 7

0 5 10 20 Kilometers

N

www.eosecology.co.nz

Layer source: Whanganui catchment and subcatchments: based on surface water management zones from Horizons Regional Council; Commercial eel fishery area: Fisheries (Central Area Commercial Fishing) Regulations 1986, regulation 3; Fish Surveys: NIWA NZFFD, downloaded 28 April 2021; Waterways: REC2 version 4 displaying stream orders 3-7.

Aerial Imagery: Sourced from the LINZ Data Service and licensed for re-use under the Creative Commons Attribution 4.0 New Zealand licence , Earthstar Geographics

The first fisheries assessment research document for tuna was published in 1994 and includes information about the fisheries for both the longfin eel (*Anguilla australis*) and the shortfin eel (*A. dieffenbachii*) within New Zealand (Jellyman, 1994). Nationally, the commercial fishery for tuna became established in the 1960s and catch volumes peaked in the mid 1970s. At this time, the commercial tuna catch was dominated by longfin eels in the Taranaki/Whanganui area, whereas shortfin eels were the dominant species caught commercially on a national scale, with an estimated two-thirds of the catch being shortfins. More recently, an analysis of catch per unit effort (CPUE) for the North Island commercial freshwater tuna fishery covered a 28-year period from 1990 to 2018 and found that although shortfin eels consistently dominate the catch (up to 89% of total tuna landings), this is not the case within the Rangitikei/Whanganui eel statistical area (ESA), where yields of longfins and shortfins were similar (Beentjes, 2020). Over this period, the Rangitikei/Whanganui ESA has contributed 7.2% of the total North Island tuna catch, with the median annual shortfin catch ranging between 50 and 280 kg per day and median annual longfin catch ranging from 10 to 160 kg per day. The median annual catch for longfin eel has declined over time, with the lowest catches reported over the last five years (Beentjes, 2020). Analyses of catch per unit effort (CPUE) for shortfin eels show that mean catch per lift was relatively stable until 2005, then started to show an increasing trend, whereas CPUE for longfin eels has shown a downward trend since 1995 (Beentjes, 2020).

The North Island tuna fishery became part of the Quota Management System (QMS) in 2005, with separate stocks established for longfin and shortfin eels. In early 2005, much of the Whanganui River catchment was closed to commercial fishing (Fisheries New Zealand, 2019). According to the Fisheries (Central Area Commercial Fishing) Regulations 1986, Regulation 3 “no commercial fisher may take aquatic life by any fishing method, or be in possession of any aquatic life taken from the Whanganui River catchment”, except for the listed excluded areas, which are: the lower Whanganui River, and any tributaries from the lower Whanganui River, below the junction of the Kauarapaoa Stream with the Whanganui River (at NZMS 260-R22, 886538, and adjacent to the historic site Kemps Pole), and all ponds and dams within the Whanganui River catchment that are not connected at any time of the year to either any one of the tributaries leading into the Whanganui River or the Whanganui River itself (Figure 3). This represents approximately the lower 30 km of the Whanganui River mainstem and includes the tributaries that join to this section of the river. Although this section of the lower Whanganui River and tributaries is available to commercial fishers, it does not appear to be highly utilised, possibly because other locations within the quota management area provide easier and more productive fishing (Duncan Petrie, Ministry for Primary Industries, personal communication, May 5, 2021).

The closure of much of the Whanganui River to commercial fishery may provide an important refuge, particularly for longfin eel. Beentjes *et al.* (2016) estimated that the total current area of habitat available to longfin eel in the North Island is 459 km^2, including rivers and natural lakes. Of this, 23% is subject to commercial tuna fishery. A recent project to identify priority areas for the protection of longfin eel identified the Whanganui catchment as a priority area, primarily because its relatively high proportion of native riparian vegetation conveys an advantage in terms of reduced risk of habitat disturbance and increased likelihood of habitat quality being maintained (Pierre *et al.,* 2014).

Levels of recreational and customary harvest of tuna are not well known (Pierre *et al.,* 2014). However, oral accounts of the customary tuna harvest in the Whanganui River suggest that annual catches were in the order of hundreds of tonnes, while 2000 large tuna could be taken in one night during the peak of the tuna heke (Potaka, 2008). In a pilot study using traditional fishing methods and timing, the Whanganui River Maori Trust Board showed that the current harvest is at least an order of magnitude less than pre-1900 levels, at around 12.5 kg per harvest (Potaka, 2008). The results suggest a substantial decrease in the frequency of large longfin eel, with catch per unit effort also low in comparison to historical accounts.

Historically, tuna fisheries were vital to the people of the Whanganui River and were abundant within the catchment. It has been estimated that as many as 350 pā tuna (eel weirs) were present along the river until the late 1800’s. These traditional fisheries were threatened in the 1900’s by regulations designed to prevent the accidental capture of trout along with traditional harvests, as well as by efforts to 'improve' the river for European navigation purposes (Knight, 2016). Furthermore, in the late 1800's, European acclimatisation societies decided that tuna were a threat to the establishment of trout in New Zealand and escalated their efforts to eradicate them, including within the Whanganui catchment.

4.1.3 Īnanga

Records from the NZFFD provide an overview of the distribution of īnanga in the Whanganui catchment (Figure 4). This shows that īnanga are typically found in the lower reaches of the Whanganui mainstem and tributaries, although there is a record of īnanga as far upstream as Kirikau. Their more widespread occurrence in the lower river is not surprising, since īnanga are known to be limited to lower gradient rivers and streams because of their inability to climb falls or swim through swift rapids (McDowell, 1990). Over all surveys recorded in the NZFFD for the Whanganui catchment, there are 24 records of īnanga, with an average abundance of 6.9 fish per record for those surveys where absolute abundance was included (Table 5).

Recent īnanga (atutahi) spawning surveys on the Whanganui River were completed at 16 sites in the lower catchment, with 12 of these on the mainstem of the river and a further four sites on tributaries (Rutledge, 2019). These surveys observed spawning sites over an 18.5 km distance on the Whanganui River, extending up to 28 km from the river mouth. The known spawning habitat on the river was extended by several kilometres compared to previous studies, with eight new spawning sites identified as part of this work. The work identified that the amount of shading, bank shape, and bank slope were the most important determinants of the number of eggs laid at spawning sites. On completion of this survey, Rutledge (2019) estimated that total productivity of the Whanganui River population was around 5.3 million eggs and concluded that the population is unlikely to be self-sustaining considering the level of existing whitebait harvest and the continued loss of suitable spawning habitat. Clearly, the protection of the known spawning sites needs to be a top priority and potential solutions have been well documented by Rutledge (2019). Existing threats to spawning sites include stock access and grazing, unstable or steep banks, weeds, public use, and rubbish. Recommended actions to protect and enhance spawning habitats in the Whanganui catchment include the control of invasive plant species, fencing to protect sites from stock access and grazing, recontouring banks to provide suitable profiles for spawning, native planting, and signage to improve public understanding of the importance of īnanga (atutahi) spawning habitat.

Table 5 Summary of New Zealand Freshwater Fish Database records of īnanga in the Whanganui catchment (1948–2019). Refer to Figure 4 for information on the distribution of these records within the catchment.

Species	Number of records	Total number of fish recorded	Mean fish abundance (per record)	Range in abundance (per record)
Īnanga (*Galaxias maculatus*)	24	124	6.9	1 to 30

4.1.4 Other Migratory Galaxiids (Kōaro, Shortjaw Kōkopu, Banded Kōkopu)

Of the three other migratory galaxiids recorded in the NZFFD for the Whanganui catchment, shortjaw kōkopu (*Galaxias postvectis*) is the most widespread (Figure 4), although kōaro (*Galaxias brevipinnis*) has been recorded in greater abundance at sites where it is present (Table 6). Result of surveys recorded in the NZFFD for the Whanganui catchment show that banded kōkopu (*Galaxias fasciatus*) and shortjaw kōkopu are typically found in similar abundances where they are present, but banded kōkopu are encountered less often than shortjaw kōkopu (Table 6).

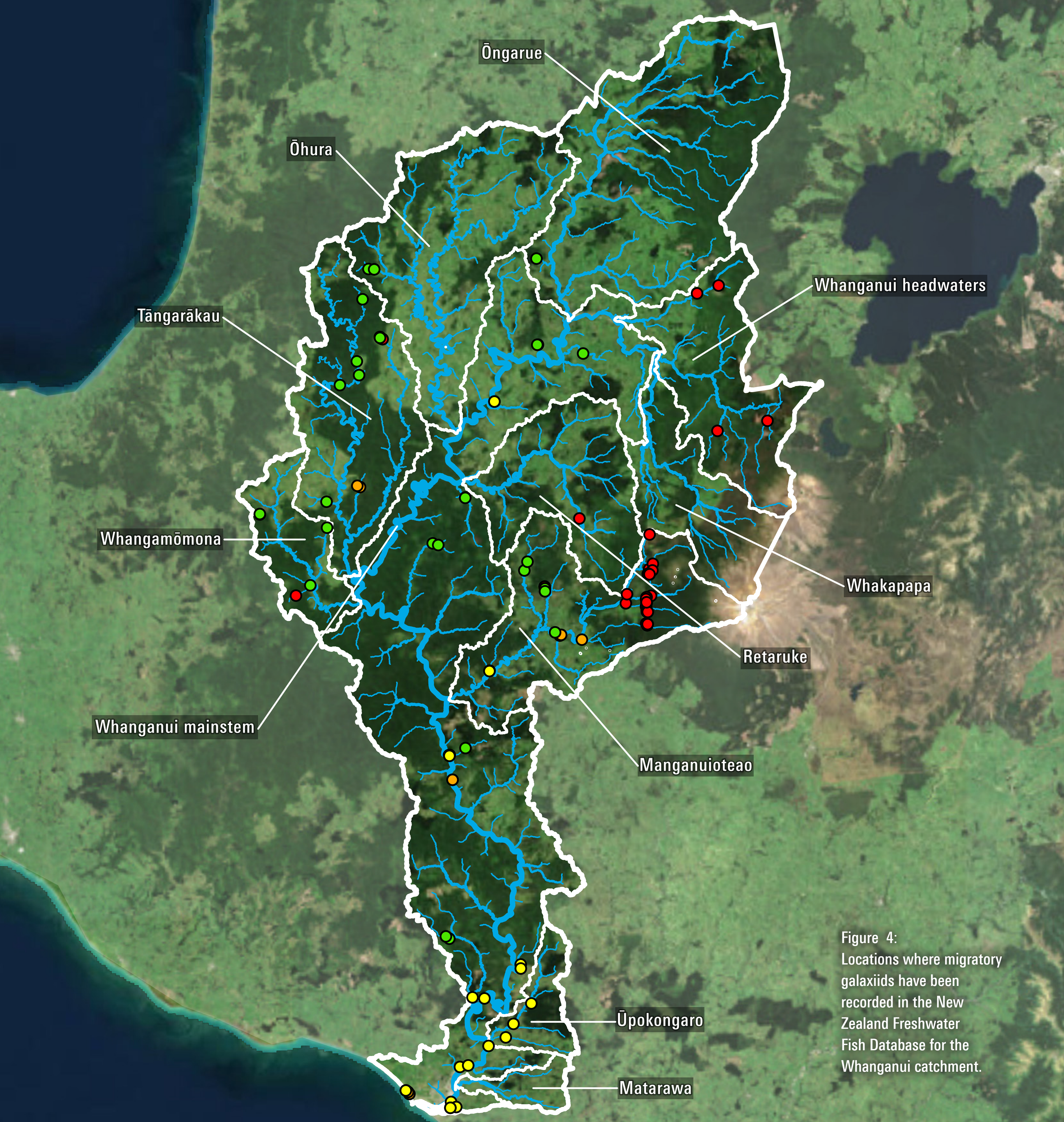

Figure 4: Locations where migratory galaxiids have been recorded in the New Zealand Freshwater Fish Database for the Whanganui catchment.

Recorded locations of galaxiids within the Whanganui River catchment

Whanganui catchment

Whanganui subcatchments

Waterways

- Stream Order 3
- Stream Order 4
- Stream Order 5
- Stream Order 6
- Stream Order 7

Location of fish surveys

- Kōaro (*Galaxias brevipinnis*)
- Banded kōkopu (*Galaxias fasciatus*)
- Īnanga (*Galaxias maculatus*)
- Shortjaw kōkopu (*Galaxias postvectis*)

0 5 10 20 Kilometers

N

Layer source: Whanganui catchment and subcatchments: based on surface water management zones from Horizons Regional Council; Fish surveys: NIWA NZFFD, downloaded 28 April 2021; Waterways: REC2 version 4 displaying stream orders 3-7. Aerial Imagery: Sourced from the LINZ Data Service and licensed for re-use under the Creative Commons Attribution 4.0 New Zealand licence , Earthstar Geographics

Table 6 Summary of New Zealand Freshwater Fish Database records of other migratory galaxiids in the Whanganui catchment (1948–2019). Refer to Figure 4 for information on the distribution of these records within the catchment.

Species	Number of records	Total number of fish recorded	Mean fish abundance (per record)	Range in abundance (per record)
Kōaro (*Galaxias brevipinnis*)	40	180	5.0	1 to 20
Banded kōkopu (*Galaxias fasciatus*)	10	18	2.6	1 to 11
Shortjaw kōkopu (*Galaxias postvectis*)	37	89	2.4	1 to 9

Turbidity is likely to play a part in the distribution of migratory galaxiids in the Whanganui catchment. In a study comparing the abundance of banded kōkopu in turbid rivers and clear rivers in the North Island of New Zealand, Rowe *et al.* (2000) found that diadromous fish were significantly less abundant in turbid rivers compared with clear rivers. The abundance of banded kōkopu showed the greatest effect of turbidity and this species was rarely recorded within the Whanganui catchment, which was included in the study as an example of a turbid river. They suggest that the recruitment of juveniles is impaired in turbid rivers, which may explain their low abundance in the Whanganui catchment, despite the existence of native bush and optimal instream habitat within this catchment.

Natural barriers to migration also influence fish distribution within the Whanganui catchment. Kōaro, shortjaw kōkopu, and banded kōkopu are very strong climbers, with the ability to migrate upstream past substantial waterfalls (McDowell, 1990). Their excellent climbing ability, compared to other native and introduced fish species, allows them to penetrate well inland to high gradient rivers and streams, where suitable habitat still exists (Figure 4). This may be especially relevant for kōaro, who are known to favour swiftly flowing forested streams of small to moderate size (McDowell, 1990). Although not widespread within the Whanganui catchment, kōaro have been recorded in the steep headwaters of the Whanganui and Manganuioteao rivers (Figure 4).

The influence of natural barriers on fish distribution was further explored with a survey of the upper and middle reaches of the Mangapurua Stream during 2011 (Petrove *et al.,* 2012). This survey found that shortjaw kōkopu were present in the upper reaches of the stream, above a cascade that appears to form a natural barrier to some species. The observation of several smaller unidentified galaxiids in this survey suggested that recruitment was occurring at these upper Mangapurua Stream sites. The findings of this survey suggest that the natural barrier, which is preventing trout access to the upper Mangapurua Stream may be highly important for the shortjaw kōkopu population in that stream. It was observed that where brown trout were present downstream of the natural barrier, shortjaw kōkopu were absent.

4.1.5 Trout

Horizons' One Plan identifies river reaches that have outstanding trout fishery values or are regionally significant within the Mānawatu-Whanganui Region. Many rivers and streams within the upper and middle reaches of the Whanganui catchment are identified for their trout fishery values and several others in the catchment, including the Manganuioteao River and Makatote River, are identified as outstanding trout fisheries (McArthur & Lambie, 2007). The One Plan also identifies trout spawning values in many rivers and streams in the upper Whanganui catchment.

The Manganuioteao, Whanganui, and Whakapapa rivers are important headwater trout rivers for both the brown and rainbow trout fisheries (Jellyman & Graynoth, 1994). The headwaters of the Whanganui River (above Ōhura) were the most heavily fished for trout within the Auckland/Waikato Fish and Game region for the 2015–

2016 season, with 4,690 ± 870 angler days recorded for the mainstem of the river, increasing to 7,980 ± 1,120 angler days when the Whanganui tributaries are included in the total (Unwin, 2016). The Manganuioteao and the Whanganui River (below Ōhura) were also among the most highly fished rivers within the Taranaki Fish and Game Region, with a further 2,140 ± 340 angler days recorded at Whanganui catchment sites within that region.

A drift diving survey of the Whanganui River downstream of the Whakapapa confluence during 1986 and 1988 counted the numbers of small, medium, and large brown trout and rainbow trout present in the river (Jowett, 1988). As many as 98 brown trout and 77 rainbow trout were counted within a 1.7 km stretch of the river and this indicated that the Whanganui River had relatively high weighted trout abundance compared to other surveyed New Zealand rivers. A further drift diving survey was undertaken in the headwaters of the Whakapapa River during 2015 and high numbers of large (40+ cm) rainbow and brown trout were observed (Daniel, 2015). This survey reported an increasing trend in the number of large rainbow and brown trout counted per kilometre of river, with records extending back to 1994.

Prior to the establishment of minimum flows below TPD intakes, these locations were often completely dry. Baldwin *et al.* (2012) undertook an electrofishing survey of the Whanganui, Mangatepopo and Whakapapa rivers below the TPD western diversion intakes. They found that brown and rainbow trout had re-established at sites below the intakes that were dry prior to the establishment of minimum flow requirements for these rivers.

A juvenile trout survey of 11 sites in the Manganuioteao catchment during 2017 found rainbow trout fry at all sites, whereas brown trout were only found at three sites and in very low densities (Maclean, 2018). Size measurements from this survey suggested that rainbow trout spawning peaked during early September in this catchment. A similar survey of four sites in the Retaruke River found brown and rainbow trout fry at all sites, although rainbow trout fry were more abundant than brown trout fry (Maclean, 2021). Size measurements from this survey suggested that rainbow trout spawning occurred in July or August in this catchment.

4.1.6 Pest Fish

The NZFFD includes records of koi carp, goldfish, catfish, and gambusia at sites within the Whanganui River catchment (Table 3). Many of these records are from isolated ponds within the catchment. The majority of these observations have been recorded by the Department of Conservation (DOC), as part of ongoing pest fish survey work in the catchment. DOC keeps a database of pest fish within the catchment and eradicates these species where possible. Therefore, it is likely that a number of the pest fish records from the NZFFD are now outdated.

4.2 Invertebrates

4.2.1 Kākahi

Kākahi (*Echyridella menziesii*) have a conservation status of *at risk – declining* (Grainger *et al.*, 2018). Numbers of kākahi in the Whanganui catchment are very low and they can be difficult to locate in areas where they were traditionally abundant (Rainforth, 2008). The decline in kākahi abundance in the Whanganui catchment has now been well documented, being noted as early as 1990 (Planning Tribunal, 1990, cited in Rainforth, 2008), and further documented in the Whanganui River Report (Waitangi Tribunal, 1999). The loss of traditional kākahi populations is described by Rainforth (2008) and local knowledge suggests that the decline became noticeable as early as the 1950's. The abstraction of water from the Whanganui headwaters for the TPD scheme is cited by iwi as a likely cause of kākahi decline, as known kākahi beds became exposed because of the drop in water levels (Rainforth, 2008). Whanganui kaumātua have identified reduced flows, increased sedimentation pollution, gravel extraction and channel modifications as key factors contributing to the decline in kākahi abundance in the Whanganui catchment (Rainforth, 2008).

A survey of 22 known kākahi beds in the Whanganui catchment by Rainforth (2008) found that there is an ongoing decline of kākahi populations, with only 18% of these sites showing evidence of juvenile recruitment, and with population decline evident for 73% of sites. This study found that catch per unit effort increased with distance upstream, suggesting that survival is higher upstream where water quality is higher. Rainforth (2008) concluded that the abundance of kākahi has declined within living memory and that few known populations within the Whanganui River are recruiting. A lack of host fish is proposed as one of the reasons for this decline, and it is suggested that intervention will be required to restore kākahi populations in the catchment, with the recommended focus being on water quality and habitat improvements for kākahi and their host fish.

Horrox (1998) also searched for kākahi at over 50 sites within the Whanganui catchment and located the species at only six sites (Pipiriki and Jerusalem sites on the mainstem of the Whanganui, Lismore Stream – a lower catchment tributary, Nixons Creek in suburban Whanganui, Hapurua Stream near the north-western boundary of the Whanganui catchment, and Kākahi Stream east of Taumaranui). Horrox (1998) found that kākahi distribution was most strongly influenced by habitat characteristics and suggested that reduced habitat stability with agricultural development may be contributing to reduced abundances of kākahi in the Whanganui catchment.

4.2.2 Kōura

As part of a study to determine habitat preferences of kōura in lower North Island streams, Brown (2009) surveyed 19 sites within the Whanganui catchment and found kōura present at 13 (68%) of these sites. Survey sites were selected based on being representative of land use patterns in the lower North Island and accessibility for day and night surveys. This study found that riparian vegetation, the presence of predators, and instream habitat characteristics were important factors in determining the presence or absence of kōura at a given location.

The NZFFD includes records of kōura, as they are often encountered during fish surveys. The NZFFD records for the Whanganui catchment include 270 observations of kōura from 210 different sites, with a total of 831 individuals counted, ranging between one and 68 individuals per site (Crow, 2018). Many records of kōura within the catchment are recorded using relative abundance categories (abundant, common, occasional, rare), rather than absolute counts, meaning that the total number of kōura observed is likely to be much higher than the individual count indicates.

4.2.3 Other Macroinvertebrates

As part of their State of the Environment (SOE) Monitoring, Horizons Regional Council undertakes annual macroinvertebrate monitoring at six sites within the Whanganui River catchment, including four sites on the mainstem (Whanganui at Cherry Grove, Whanganui at Te Maire, Whanganui at Wades Landing, and Whanganui at Pipiriki), as well as Ōngarue River at Taringamotu and Manganuioteao River at Ashworth (Land, Air, Water Aotearoa, 2021; Figure 5). The Macroinvertebrate Community Index (MCI; Stark, 1985) is used to provide an indicator of water quality for these sites.

Data from these SOE sites in the Whanganui catchment shows low variability among sites, with all sites having mean MCI values of between 101 and 113 over the period of sampling, indicating ‘good’ water quality (Table 7). An average of between 22 and 28 macroinvertebrate taxa were collected at each site and the percentage of Ephemeroptera, Plecoptera, and Trichoptera (EPT) taxa was between 43 and 56%.

Table 7 Summary of macroinvertebrate community indices for the six sites in the Whanganui River catchment monitored annually by Horizons Regional Council. Mean ± SE is presented for Macroinvertebrate Community Index (MCI), taxa richness, and % Ephemeroptera, Plecoptera, and Trichoptera (% EPT taxa). Refer to Figure 5 for information on where these sites are located.

Site location	Years of survey	Number of surveys	MCI	Taxa richness	% EPT taxa	MCI Interpretation (Stark & Maxted, 2007)
Whanganui at Cherry Grove	2005–2019	15	111 ± 2.2	25 ± 1.2	53 ± 2.2	'Good' water quality
Whanganui at Te Maire	1991–2019	43	111 ± 1.3	23 ± 0.9	50 ± 1.2	'Good' water quality
Whanganui at Wades Landing	2005–2019	15	106 ± 1.5	26 ± 1.2	48 ± 1.2	'Good' water quality
Whanganui at Pipiriki	2005–2019	15	101 ± 1.7	22 ± 1.6	43 ± 1.5	'Good' water quality
Ōngarue at Taringamotu	2013–2019	7	112 ± 2.3	28 ± 2.7	55 ± 2.0	'Good' water quality
Manganuioteao at Ashworth	2009–2019	11	113 ± 3.4	28 ± 1.7	56 ±3.8	'Good' water quality

In addition to annual SOE monitoring, there have been two key studies on macroinvertebrate communities in relation to either geology and/or catchment land use within the Whanganui River catchment. Davies-Colley & Stroud (1995) compared forested and pasture streams in their work on the Whanganui catchment. They surveyed the macroinvertebrate community at two sites, Prospect Creek and Awahou Stream (both tributaries of the Whangamōmona River), as part of a paired catchment study comparing forested with pasture subcatchments. They found that the pasture stream (Prospect Creek) supported a lower diversity and higher abundance of macroinvertebrates than the forested stream (Awahou Stream) in their study. This resulted in the pasture stream having a lower Macroinvertebrate Community Index (MCI) score and lower proportions of pollution sensitive Ephemeroptera, Plecoptera, and Trichoptera (EPT) taxa than the forested stream. Whereas only eight macroinvertebrate taxa (2.5% EPT) were recorded in the pasture stream, they found 24 taxa (28% EPT) in the forested stream.

Horrox (1998) investigated not only the effects of land use on macroinvertebrate communities, but also geology in his survey of 47 sites within the Whanganui catchment (Figure 5). This appears to be the most comprehensive survey of macroinvertebrates that has been undertaken in the catchment to date, with the sampling sites distributed across the catchment and including at least one site in each of the subcatchments identified in this review (Figure 5). Horrox (1998) suggested that the impacts of pastoral land use on macroinvertebrate communities are accentuated by the soft sedimentary geology of these catchments. The survey found that forested streams in mudstone catchments support a diverse community of pollution sensitive macroinvertebrate taxa (such as EPT taxa), whereas streams within pastoral agriculture in mudstone catchments support a lower diversity and abundance of pollution sensitive taxa. The gastropod *Potamopyrgus antipodarium* dominated mudstone pasture streams in this study (average 45% of individuals), whereas Ephemeroptera (mayflies) dominated the mudstone forest streams.

Differences in macroinvertebrate community structure based on geology and land use have implications for catchment management and may provide a focus for prioritising restoration efforts. The Horrox (1998) study showed that taxonomic richness and diversity in forested mudstone streams was similar to that of hardstone streams, whereas mudstone pasture streams had a lower diversity. The lower abundance and diversity of macroinvertebrates in mudstone pasture streams suggested that these are more susceptible to the impacts of agricultural development.

The lower Whanganui River is not regularly surveyed for macroinvertebrates, with the downstream-most state of the environment monitoring site being located at Pipiriki (Table 7, Figure 5). However, Horrox (1998) used artificial substrates and kicknet sampling to survey macroinvertebrates at five sites on the mid-Whanganui River mainstem, between Taumaranui and Kaiwhaiki. He found that water clarity and periphyton biomass decreased downstream, as did taxonomic diversity and the abundance of sensitive invertebrate taxa (i.e., EPT taxa), suggesting that the changes to invertebrate community structure were influenced by the changes to periphyton biomass and increase in suspended solids associated with pastoral land use.

Other one-off macroinvertebrate surveys within the catchment have been undertaken for specific purposes, such as blue duck conservation. James (2008) surveyed macroinvertebrates at three sites in the Manganuioteao River to document the baseline condition of macroinvertebrates and algae in the river, in the face of concerns that *Didymospenia geminata* may invade this river and that the main food supply for blue duck could be impacted if this were to occur. This survey was undertaken during autumn (April 2008) and found that the upstream most site supported the highest proportion of sensitive EPT taxa (~60%) and that these declined downstream to around 25%. Values for MCI and QMCI also declined downstream, although the downstream most survey site at Makakahi Road supported the highest density of macroinvertebrates and had the greatest number of taxa present. The survey was repeated in spring (November 2008) and showed similar downstream trends, although macroinvertebrate densities were generally higher for all sites at the November survey (James, 2010a). For the same reasons, benthic macroinvertebrate surveys were undertaken at three sites in the Retaruke River, during April and November 2008 (James, 2010b). For the Retaruke River, the percentage of EPT individuals and taxa declined from upstream to downstream and the MCI and QMCI values indicated declining water quality downstream. The density of macroinvertebrates also declined from upstream to downstream, but higher densities of macroinvertebrates were collected during the November sampling for all sites.

Upper Whanganui catchment rivers and streams have been the focus of macroinvertebrate surveys and monitoring in relation to the western diversion of the TPD. Macroinvertebrate surveys to support the resource consent application for the TPD were undertaken at sites upstream and downstream of western diversion intakes on the Whanganui, Mangatepopo, Tawhitikuri, Taurewa, Okupata, and Whakapapa streams. These surveys found that there was no consistent difference between sites upstream and downstream of intakes, and that these streams support healthy macroinvertebrate communities with high MCI scores (Jowett *et al.*, 1999; Genesis Energy Limited, 2000). These reports indicated that there was a reduction of instream habitat below the intake diversions, resulting in a reduced number of invertebrates living in these streams, but that the invertebrate community composition is relatively unchanged by the diversions. Monitoring of macroinvertebrates at sites upstream and downstream of intake structures on the Whanganui, Mangetapopo, and Whakapapa rivers is undertaken as part of the ongoing TPD monitoring programme (Tonkin & Taylor Limited, 2013; Tonkin & Taylor Limited, 2015). This monitoring has shown that percentage EPT, MCI and QMCI scores are high at both upstream and downstream sites and that the values are indicative of 'excellent' water quality at these sites (Genesis Energy Ltd, 2015; Tonkin & Taylor Limited, 2013; Tonkin & Taylor Limited, 2015).

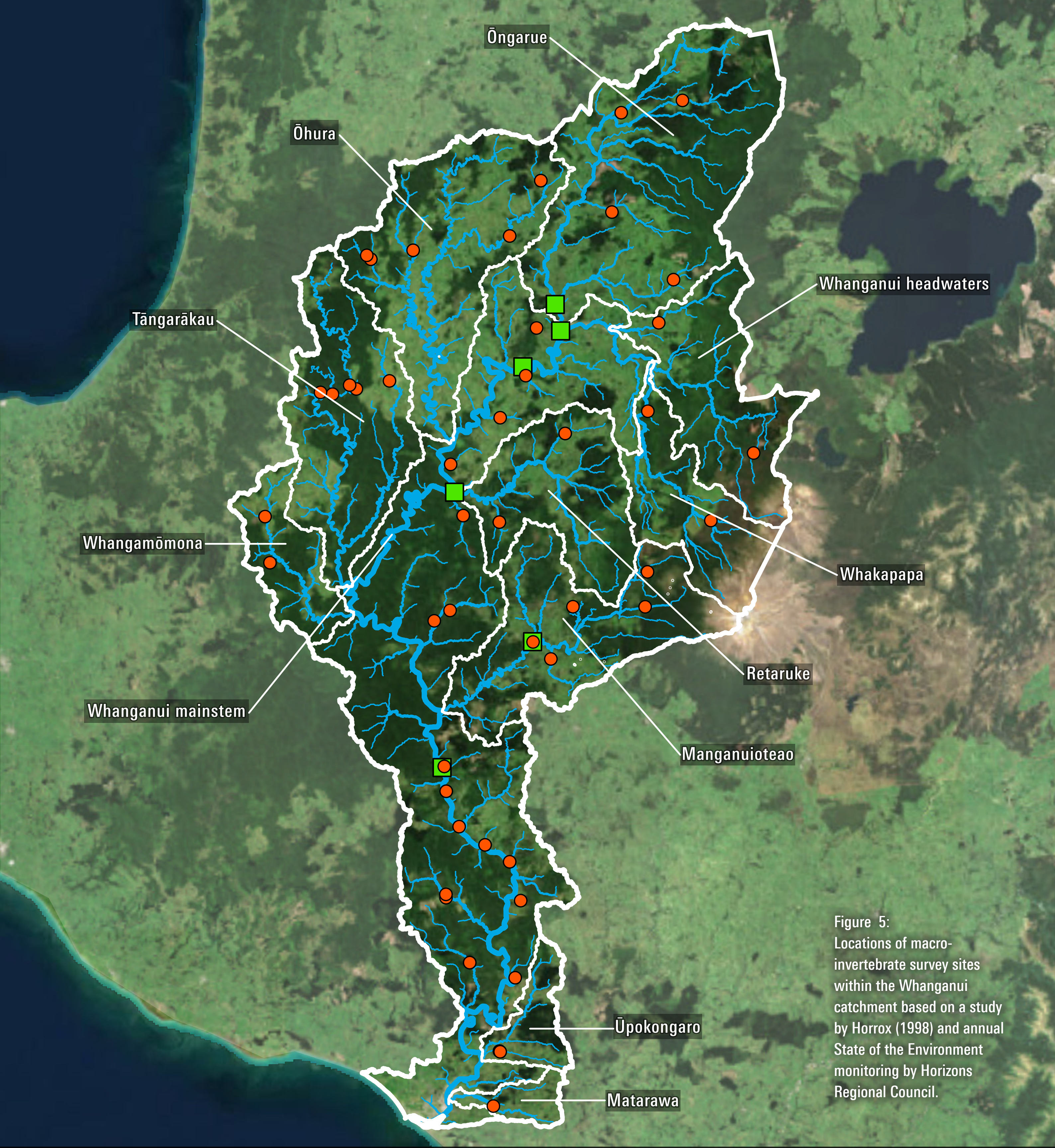

Figure 5:
Locations of macro-invertebrate survey sites within the Whanganui catchment based on a study by Horrox (1998) and annual State of the Environment monitoring by Horizons Regional Council.

Locations of macroinvertebrate surveys within the Whanganui River catchment

Whanganui catchment

Whanganui subcatchments

Horrox (1998) - One off survey

Horizons Regional Council - State of the Environment sampling

Waterways

Stream Order 3

Stream Order 4

Stream Order 5

Stream Order 6

Stream Order 7

0 5 10 20 Kilometers

N

Layer source: Whanganui catchment and subcatchments: based on surface water management zones from Horizons Regional Council; Macroinvertebrate surveys: Horizons Regional Council and Horrox 1998; Waterways: REC2 version 4 displaying stream orders 3-7.

4.3 Aquatic Birds

4.3.1 Whio (blue duck)

The central North Island of New Zealand is a crucial location for several key populations of whio. The population within the Manganuioteao catchment was the subject of a comprehensive study of the social and demographic characteristics of whio, with surveys undertaken in the catchment between 1979 and 1989 to establish population size and trends over time (Williams, 1991). This study found a slowly increasing population of whio in the Manganuioteao catchment following a lahar that devastated the population in 1975. By 1987, 36 pairs of whio were recorded within the surveyed reaches of the river, and the catchment was thought to support one of the largest known breeding populations in the North Island.

Understanding the importance of the central North Island whio populations, the Department of Conservation established a goal "to maintain, expand existing, and establish new self-sustaining whio populations on key central North Island river systems" (Etheridge & Peet, 2004). Towards this goal, an objective was set to secure a minimum population of 40 pairs of whio at prescribed management sites, including sites on the Whakapapa River, upper Whanganui River, Mangatepopo Stream and Manganuioteao River. Predator control was implemented in these selected catchments, with both predator trapping and aerial 1080 drops beginning during 2007. Monitoring programmes were also established at this time, to assess the productivity and survival of whio in these locations.

Bristol *et al*. (2008) reported on the whio monitoring at central North Island management sites and showed that there was an overall increase in territorial pairs from the 2005/06 survey season to the 2007/08 survey season. They also showed that pair density increased over this time, from an average of 0.9 pairs per km to 1.1 pairs per km, and that the productivity of breeding pairs was higher for the 2007/08 season compared with previous years. There were 94 juveniles successfully fledged and adult survival of territorial pairs was nearly 87% for the 2007/08 season. Results of whio population monitoring suggested that the central North Island populations were benefitting from intensive predator control at these key management sites, with increased productivity being attributed to the aerial 1080 operations in combination with ongoing trapping effort (Bristol *et al.*, 2008).

Further to the intensive predator control and trapping that was occurring in the central North Island rivers (Bristol *et al.*, 2008), the Department of Conservation established eight high priority security sites for whio in 2006, where intensive management and predator control would be ongoing to ensure that populations are secured (Department of Conservation, 2021). Over 50 km of the Manganuioteao and Retaruke rivers form one security site, while the Tongariro Forest security site includes reaches of the Whakapapa, Whanganui, and Mangatepopo rivers. The goal of security sites is to secure 50 pairs of whio within a predator-controlled area (Glaser *et al.,* 2010).

Ongoing monitoring supports the success of the whio security areas. During the 2008/09 breeding season, 33 pairs of whio were present within the Manganuioteao and Retaruke security site and ongoing monitoring suggests that survival and productivity at this site has improved compared to rivers without predator control (Campbell & Bristol, 2010). Survey results indicate that with ongoing predator control in place, the main issues for these whio populations are natural events such as floods, droughts, and food availability, rather than predation by introduced predators (Campbell & Bristol, 2010). During the 2009-2010 breeding season, 65 pairs of whio were recorded within the Manganuioteao and Retaruke security site, with 37 pairs found within the Manganuioteao catchment and a further 28 pairs in the Retaruke River (Campbell *et al.*, 2010). The predator control within this security site is credited with the high survival rate of adult males (100%) and females (98.5%), and the high rate of duckling survival, with over 80% surviving to fledge (Campbell *et al.*, 2010). Favourable results have also been reported for the Tongariro Forest security area. At the end of the 2008/09 season, there were 36 pairs in the Tongariro Forest security area; an increase of 6 pairs since regular surveys began at this security site in 2004/05 season (Beath *et al*., 2009). The productivity of the Tongariro

Forest population has also increased substantially following the implementation of predator control, with increases in both the number of chicks hatched and the number of chicks fledged (Beath *et al.,* 2009).

There has also been extensive monitoring of whio in relation to the TPD. Don (1995) collated whio survey data from populations in the Western Diversion area of the TPD, including the Whakapapa catchment. They found that consistent and reliable surveys of whio in the area commenced around 1989, around 17 years after the power scheme intakes were commissioned. Records indicate that the Whakapapa catchment upstream of the intake supported a total of 24 adult whio, at a density of 1.8 individuals per kilometre in 1994, whereas there were 17 adult birds observed downstream of the intake (to below Otamawairua confluence), at a density of 2.4 individuals per kilometre.

Ongoing whio monitoring undertaken by the Department of Conservation for Genesis Energy Ltd includes survey sites on Western Diversion rivers, including the Mangatepopo Stream, Whanganui River and Whakapapa River (Swanney, 2014). These annual surveys were initiated in 2003 to determine the distribution of whio downstream of intake structures and assess the effectiveness of minimum flows that were established in 2004. Surveys were undertaken annually between 2003 and 2011, then at three yearly intervals since that time. Swanney (2014) reported that over a river distance of 47.9 km, a total of 114 pairs of whio and 218 ducklings were observed in the 2014 survey. This represented an increase of 23 pairs since the previous survey three years earlier and resulted in an average density of 2.4 whio pairs per kilometre. Beath (2018) reported that over a river distance of 52.2 km, a total of 121 pairs of whio and 252 ducklings were observed during the 2017 survey, with an average density of 2.3 pairs per kilometre, but up to 5.6 pairs per kilometre for one of the surveyed reaches on the Whanganui River.

With over two decades of monitoring of whio on western diversion rivers, the data set now provides a valuable record of the growth of the whio population in the central North Island. The records demonstrate the importance of the minimum flow establishment and intensive predator control efforts that have been crucial to the success of this whio population.

5 KNOWLEDGE GAPS, RESEARCH NEEDS & RECOMMENDATIONS

5.1 Recommendations for Further Survey Work

- **Widespread fish survey work**: The Whanganui catchment has been extensively surveyed over time by various organisations, as shown by the records available in the NZFFD (Figure 2). However, many of these surveys were carried out more than 10 to 20 years ago, and revisiting sites where there are no recent surveys will be important, especially to establish baseline ecological values when restoration works are planned. There are some subcatchments that have received relatively little survey attention, including the Ōhura, Whangamōmona, and several small lower river tributaries. Given the large area of the catchment and the difficulty of accessing remote parts of the catchment, there is potential for the rapidly evolving science of environmental DNA (eDNA) to provide a practical and cost-effective method of gaining knowledge of the fish and aquatic invertebrate communities of streams that are difficult to access. The 35 sites surveyed by Rowe *et al.* (1989) would provide a good starting point for an updated survey of the mid to lower reaches of the catchment. This survey suggested that the Whanganui River had a relatively depauperate fish community compared to other North Island rivers and recommended a comprehensive summer survey to confirm this.

» **Targeted fish survey work**: The Department of Conservation (DOC) has previously used Freshwater Ecosystems of New Zealand (FENZ) to identify focus areas for fish surveys, including using river rankings for ecosystem types on a national scale, as well as within the local biogeographic unit (Petrove, 2013). Using this method in combination with existing survey information from the NZFFD, Petrove (2013) identified several rivers and streams within the Whanganui catchment where there are gaps in the knowledge of freshwater fish distribution (Table 8). McQueen (2014) identified further gaps where freshwater fish surveys were recommended within the catchment. See Petrove (2013) and McQueen (2014) for further details.

Table 8 Summary of freshwater fish survey gaps previously reported for the Whanganui catchment (Petrove, 2013; McQueen, 2014).

Waterway	Reason recommended for survey	Last survey in NZFFD (Crow, 2018)
Mangatiti Stream	Top 20% of rivers nationally (Petrove, 2013)	Not surveyed since 1993
Tāngarākau River	Top 20% of rivers nationally (Petrove, 2013)	No survey records in NZFFD
Whenuakura Stream	Top 20% of rivers nationally, potential pressure water abstraction (Petrove, 2013)	No survey records in NZFFD
Mangaio Stream	Top 20% of rivers nationally (Petrove, 2013)	Not surveyed since 1993
Kaiwhakauka Stream	Top 20% of rivers nationally (Petrove, 2013)	Spotlight survey 2014
Mangawaiti Stream	Ranks highly at regional scale (Petrove, 2013)	No survey records in NZFFD
Ōngarue River (lower reaches)	No previous surveys in lower river (McQueen, 2014)	No lower river records in NZFFD
Kakahi Stream	No previous surveys (McQueen, 2014)	No survey records in NZFFD
Mangoihe Stream	No previous surveys (McQueen, 2014)	No survey records in NZFFD
Tangarākau River (lower reaches)	No previous surveys in lower river (McQueen, 2014)	No lower river records in NZFFD

» **Targeted pest fish survey work:** During 2019, DOC contracted Wildlands Consultants Ltd to provide recommendations for pest fish survey sites based on available geospatial information. Sites were selected based on the risk of establishment of the pest species, the proximity of the site to known pest fish infestations (risk of incursion), the biodiversity values of the site or nearby sites, public access to the site that would influence the risk of pest fish incursion, the connection or isolation of the site in relation to other waterbodies, the appearance of the site, and the proximity to other survey locations. This list provides a starting point for targeted pest fish survey work, although further prioritisation may be required.

» **Widespread macroinvertebrate survey work**: Although macroinvertebrates are monitored annually at six sites in the catchment as part of Horizons' State of the Environment monitoring programme, there has been no widespread survey of macroinvertebrates in the catchment since the work by Horrox (1998). It would be timely to undertake a resurvey of these sites, to enable comparisons over the 20+ years since this survey. More targeted macroinvertebrate surveys would be justified in locations where restoration work is planned, to establish baseline values that may be useful as indicators of the success of restoration activities.

5.2 Recommendations for Research to Fill Knowledge Gaps

» **Identify and map natural barriers to fish migration:** McQueen (2014) showed that tributaries of the Whanganui River are often lacking in fish species and numbers because of natural barriers blocking access for non-climbing species and limiting passage for climbing species. This work suggested that tributaries that are accessible to non-climbing species have higher conservation values as fish habitat and highlighted the importance of identifying and mapping these significant sites and natural barriers to migration. Work to identify and map natural barriers to fish migration could begin with a desktop analysis of known fish distribution to identify likely barriers, but it would be essential to draw on local knowledge and undertake field investigations to identify the positions of waterfalls and other natural or artificial fish barriers within the catchment. The preparation of a GIS layer of known fish barriers would support decision making around future fish survey work and would provide useful information for the purposes of planning and prioritising catchments for conservation and restoration. There may be potential to collaborate with Horizons Regional Council in this area. Horizons is currently undertaking a Jobs for Nature funded programme to identify, prioritise, and remediate barriers to fish passage within the Manawatū-Whanganui Region.

» **Environmental DNA (eDNA):** This method is potentially a practical and cost-effective way of gaining knowledge of fish and macroinvertebrate distributions within the catchment. The information it can provide on the presence/absence of fish species may be useful for narrowing down locations for further field surveys or identifying catchments where pest fish work may be necessary. As discussed in Section 5.1, it may be a technique that can support widespread fish surveys within the catchment, although further research and testing of this technique is needed to understand its reliability. It is recommended that eDNA techniques are incorporated into research programmes within the Whanganui catchment, because as a non-invasive survey technique its use could be particularly beneficial to vulnerable species (e.g., kākahi), or difficult to detect (e.g., piharau) species within the catchment.

» **Piharau surveys and research**: The NIWA piharau study, using Polar Organic Chemical Integrative Samplers (POCIS) to detect the presence of a piharau specific pheromone in stream water, provides a useful starting point for further investigation of piharau within the Whanganui catchment (Baker *et al.,* 2016). The report recommends resurvey for several sites where samplers were disturbed during the original study and highlights the need to prioritise catchments to ground truth the POCIS survey results and determine the extent of critical habitats for both spawning and larval rearing in these identified catchments. It is recommended that a combination of contemporary and traditional methods be used to further investigate the state of the piharau population in the Whanganui River catchment. This could include the reconstruction of traditional fishing methods, as described in Potaka (2015), further work with pheromone tracing as per the recommendations of Baker *et al*., (2016), or the addition of eDNA survey techniques.

» **Īnanga (atutahi) spawning research and monitoring**: It is recommended that research continues into the location and extent of īnanga (atutahi) spawning habitat within the Whanganui River and tributaries. This research will be needed to support the restoration and ongoing management of īnanga (atutahi) spawning sites, and to increase understanding of the potential impacts of climate change on spawning locations and timing for this species. Rutledge (2019) concluded that the population of īnanga in the Whanganui is unlikely to be self-sustaining and indicated that the protection of the known spawning sites needs to be a top priority. Therefore, further research is justified to identify existing sites.

» **Impact of trout on shortjaw kōkopu**: Previous survey work by Petrove *et al.* (2012) indicated that trout may be impacting the distribution of shortjaw kōkopu in the Mangapurua Stream. It is recommended that targeted research be used to investigate the impact of trout on shortjaw kōkopu populations in this and other streams where natural barriers are excluding trout from some reaches. This research could also investigate potential sites where trout removal may be an advantage for native fish populations. This type of research would be informative for the conservation and management of this native fish species within the Whanganui catchment.

5.3 Recommendations for Biodiversity Information Management

» **Development of pest fish database and GIS resources**: Recommend the establishment of a robust database to collate the available pest fish information for the Whanganui catchment, document locations of interest, and include outcomes of pest fish eradication activities. Existing information could be collated and organised into a simple database, enabling reporting and mapping of existing and future data collected about pest fish for the catchment. It is anticipated that eDNA work within the catchment could increase the number of pest fish records for the catchment and it will be important to have a robust system to record and action this information as it becomes available.

» **Establish electronic references library for Whanganui biodiversity resources**: Recommend that DOC establish an electronic references library to provide easy access to biodiversity references relevant to the Whanganui River. There is a large collection of historic and modern biodiversity reporting relevant to this catchment and it is essential that this body of information can be easily accessed and referred to as needed, particularly to avoid the duplication of effort and to ensure comparability with future survey work. Ongoing and future research and monitoring work should be added to this resource as it becomes available. It is also recommended that a copy of Woods (1964) be sourced for the DOC reference library, as this is one of the only fish surveys undertaken before the commissioning of the Western Diversion and should provide a valuable historic reference on the fish of this catchment.

5.4 Recommended Priorities for Restoration

» **Priority sites for riparian management or catchment revegetation**: Catchment revegetation must be a priority in terms of reducing sediment supply to the catchment because ecological values appear to be impacted by the high suspended sediment loads in the river. Research by Horrox (1998) suggested that land use combines with catchment geology to accentuate adverse impacts in mudstone catchments, leading to the conclusion that restoration efforts should prioritise soft sediment/mudstone catchments within pastoral land use. It would be appropriate to focus on riparian planting and fencing in these catchments, with the expectation that they may need wider than typical riparian buffers to reduce the effects of fine sediment entering the waterways. Research by Davies-Colley (1995) suggested that riparian management, soil conservation, and improved farm management practices would be needed to improve water quality and habitat condition of the Whanganui mainstem and tributaries. They also recommended that further research should be undertaken to examine the costs and benefits of whole catchment retirement from grazing, compared with riparian fencing, or planting and good grazing practices. It is likely that a combination of these methods will be required to improve outcomes for the Whanganui catchment.

» **Īnanga (atutahi) spawning habitat protection and restoration**: Ongoing īnanga (atutahi) spawning surveys in the lower Whanganui River and tributaries are working to establish the extent of existing spawning areas within the catchment. The īnanga (atutahi) spawning survey reported by Rutledge (2019) concluded that the īnanga population in the catchment is unlikely to be self-sustaining considering the level of existing whitebait harvest and the continued loss of suitable spawning habitat. Therefore, the protection and restoration of īnanga (atutahi) spawning habitat within the Whanganui catchment should be a high priority, and Rutledge (2019) has already recommended site-specific actions to get this work underway. With many spawning sites being in publicly visible and accessible reaches of the Whanganui mainstem and tributaries, restoration work will also be visible to the public. Therefore, community engagement and education should form a part of the work programme, to develop community support and understanding for the work, improving its chances of success. Rutledge (2019) recommended raising awareness on the importance of protecting spawning habitats and promoting a collaborative approach to developing a long-term catchment wide plan and work programme to locate and protect īnanga spawning and adult habitats.

» **Restoration of sites to support kākahi populations**: Suitable sites for restoration may be identified by engaging with mātauranga Māori (Māori knowledge or intellectual property. Sites where kākahi traditionally flourished would be a priority and reduction of sediment inputs (via measures such as catchment revegetation) will be a crucial component of restoration. The distribution of kōaro is also an important consideration, as these are the host fish for the parasitic larval stage of the kākahi. A restoration and adaptive management approach may be most appropriate in this situation. Additional surveys may be required to support the selection of suitable restoration sites, including an extensive survey of kākahi within the catchment, as recommended by Rainforth (2008). Initial eDNA surveys of the catchment may be useful to establish the overall presence/absence of kākahi, followed by population density and distribution studies. Assessments of recruitment and age groups would also be needed to establish where there are existing sustainable populations. Further research is also needed to determine the causes of kākahi decline in the Whanganui catchment, as this is still unclear.

- **Include cultural perspectives when measuring restoration success for Te Awa Tupua**: Collier (2017) provides a useful guide to measuring the success of river restoration projects, especially where multiple stressors are involved, as is the case for the Whanganui River catchment. This paper also highlights the importance of including cultural perspectives in measuring restoration success. Including appropriate cultural measures will be crucial for measuring the success of any restoration work on the Whanganui River and I would recommend this paper as a starting point for exploring this topic further, along with obtaining input directly from the hapū of the awa and from Ngā Tāngata Tiaki o Whanganui. For example, the work by the Whanganui River Maori Trust Board (WRMTB; Potaka, 2008) comparing oral history accounts of total annual catches with surveys using traditional fishing methods and timing could be used to measure the success of any restoration attempts related to the tuna/eel population in the catchment.
- **Tongariro Power Scheme (TPS) migrant tuna/eel transfers**: The work by Smith *et al.* (2015) reported on the numbers of migrant tuna that have been manually transferred to the headwaters of the Whanganui River. This report shows that the area within the TPS supports some tuna productivity that may contribute to the population within the Whanganui catchment if support is provided for migrant tuna to navigate the barriers that exist as part of the TPS. It is recommended that the work to transfer migrant tuna from the Wairehu drum screen be continued, and alternative solutions be investigated, to provide connections between the habitat upstream of the TPS with the rest of the catchment.
- **Native fish and invertebrate vulnerability to climate change**: The vulnerability of New Zealand's freshwater taonga species has been assessed using a Climate Change Vulnerability Assessment (CCVA), which identifies which species are most vulnerable based on their exposure to predicted changes in the environment and their sensitivity to changes based on known characteristics of the species (Egan *et al.,* 2020). This assessment indicates that longfin eel and piharau have very high vulnerability to climate change. Shortfin eel, banded kōkopu, īnanga, kōaro, and kākahi have high vulnerability to climate change. Giant kōkopu and kōura have moderate vulnerability and yellow eye mullet have low vulnerability to climate change. The Whanganui River supports significant populations of both longfin eel and piharau, the two species considered to be at the greatest vulnerability to climate change. The catchment also supports populations of those species with high vulnerability to climate change (shortfin eel, banded kōkopu, īnanga, kōaro, and kākahi). The reasons for longfin eel having very high vulnerability include their complex lifecycle, long migrations, use of environmental triggers, and the multiple threats that the species already faces (Egan *et al.,* 2020). For piharau, their very high vulnerability is linked to the low larval dispersal, habitat specificity, reproduction complexity, exposure to other pressures and their dependence on other species as part of their lifecycle. The vulnerability of īnanga to climate change is also linked to the complexity of their lifecycle, with their specific requirements for spawning grasses and appropriate water levels being key factors in their vulnerability. Given the vulnerability of these species to climate change, it is recommended that there is a focus on reducing other stressors on these species and supporting known populations so that they are better placed to cope with the anticipated impacts of climate change.

» **Whio vulnerability to climate change**: Floods are a natural part of the environment for whio populations, but large floods can have a devastating effect on whio productivity, depending on their timing in relation to the breeding season (Swanney, 2014). With the potential for climate change to influence the timing and frequency of floods, whio populations may also be vulnerable to the impacts of climate change. This provides additional justification for the ongoing support of the whio population within the Whanganui River catchment and for the continuation of whio monitoring programme within the catchment. It is important to continue this population monitoring, as the existence of a consistent long-term record may be especially valuable to predict and manage for potential changes in environmental conditions.

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